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PREVENTION OF PREMATURE SHOTS DURING SPRINGING OF DEEP DRILL HOLES IN QUARRIES AND OPEN-PIT WORKINGS

BY

D. HARRINGTON AND C. W. OWINGS

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By D. Harrington[2] and C. W. Owings[3]

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INTRODUCTION

Springing or chambering of deep drill holes is common practice in some quarries. It involves definite hazards from premature explosion during placing of the springing charges or the final charge due chiefly to heating of the bottom of the holes by the successive exploding of the springing charges or, in some instances, from burning of paper or other material following detonation of the explosives. The danger is either unknown or disregarded in many instances by those who place the charges in the holes. Disregard of this hazard probably is, at least in part, responsible for the far too high fatality and injury rate due to charging explosives and premature shots in quarry work. Awareness of the danger should result in elimination or at least of material decrease in injuries from this cause.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7191."

[2] Chief, Health and Safety Branch, Bureau of Mines, U.S. Department of the Interior, Washington, D. C.

[3] Mining engineer, Bureau of Mines, U.S. Department of the Interior, Pittsburgh, Pa.

HAZARD FROM SPRINGING HOLES

The hazard of placing explosives in holes to spring them, or of placing final charges in sprung holes, may be better understood from descriptions of accidents.

During the summer of 1938, several holes about 25 feet deep were sprung in a large open pit by firing four 3- by 10-inch cartridges of gelatin dynamite in each hole. Three holes were sprung, and the final charges were placed immediately after the hole had been fired. The chamber in the fourth hole was believed to be too small, and it was sprung the second time. The hole was loaded immediately with 5 cases of free-running bag explosive, and the charge had been tamped within 6 feet of the collar of the hole when, while the blaster was still tamping the charge the hole exploded. Only the bottom of the hole was broken, and the blaster was not injured, although he was considerably "shaken up." The opinion of the person who made the investigation was that burning, loose paper from the springing charge ignited the explosive, which did not explode until enough pressure had developed, owing to its slow-burning characteristics.

A premature explosion of undetermined origin occurred in a drill hole in a quarry in July 1936, which resulted in injury to two men. As soon as drilling was completed, springing was started by placing one cartridge of explosive and a primer in the hole. The shot failed. A second cartridge and another primer were placed in the hole, and the charge was fired successfully. Five cartridges were then put in the hole, and while the fuse on the primer was being lighted before placing the primer in the hole, the 5 cartridges exploded. No definite conclusion was reached as to the cause of the premature explosion, but it appears probable that the bottom of the hole was still hot from the springing shot, and the heat detonated the subsequent charge.

A number of similar premature explosions have been reported, but no conclusions were drawn as to causes. Two elements - frictional impact and burning - appear to be the likely causes in some of these instances and the time elapsed between placing the charge and detonation generally precludes the possibility of frictional impact, leaving burning as the most plausible cause of detonation.

CAUSES OF HOT HOLES

Holes are sprung by firing one to six or more charges of explosives in the bottom of the holes. Each charge generally contains more explosive than the preceding charge. Some dynamite develops temperatures as high as 6,000°; consequently the surrounding rock is highly heated. Successive charges in the same hole tend to raise the temperature of the rock. Some explosives cause the paper wrappings to ignite and burn more or less slowly. The final result is that the temperature of the rocks and air in the bottom of a sprung hole may be high enough to ignite the explosive charged after springing.

High explosives may burn in open air without exploding, especially if they are not piled so that pressure can develop; in the bottom of a drill hole explosives being charged into the hole may ignite and burn until pressure develops to the point where detonation occurs. It seems possible also that the paper covering of sticks of explosives may be left more or less intact after detonation of a springing charge and can smolder for a considerable time owing to the small amount of oxygen available or lack of movement of air to fan it into flame.

A similar condition may have caused the premature explosion that occurred in a limestone quarry in July 1933, when a charge of black blasting powder was placed in a drill hole that had been sprung 24 hours before.

METHODS OF SPRINGING HOLES

Oklahoma

Oklahoma law prohibits springing holes on shift. In one plant holes 1-1/4 inches in diameter and 12 to 25 feet in depth, horizontal or dipping slightly, are drilled on shift. The springing charge ranges from 5 to 15 cartridges of 1-1/4- by 8-inch dynamite of 25-, 30-, or 40-percent strength. Ordinarily gelatin dynamite is used in wet holes and ammonia dynamite in dry holes. The sprung holes are flushed with water by means of a 1-inch hose with a 1/2-inch iron pipe 16 to 18 feet long attached to the end and placed in the hole; water pressure ranges from 80 to 120 pounds per square inch. After being flushed, the hole is "blown out" with compressed air.

The springing charge is fired at the end of one shift, and the hole is recharged at the end of the next shift - an interval of 24 hours. The main charge consists of 50 to 150 cartridges of dynamite.

Kansas

Overburden in coal-stripping pits is removed by drilling and blasting the rock and earth, and then removing the broken material with power shovels. Two representative operations indicate methods of springing holes. One uses 2-inch holes 25 to 40 feet deep. These are sprung three times with 20- and 40-percent-strength gelatin dynamite. The first springing charge consists of 2 cartridges of 1-1/4- by 8-inch gelatin dynamite, the second charge is 4 cartridges, and the third charge is 6 cartridges. At least half an hour must elapse between the firing of one and the placing of the next springing charge, and between the last springing charge and the final charge consisting of 4 to 6 kegs of FF black blasting powder. As an additional precaution, a small piece of pipe is lowered by a rope to the bottom of the hole, where it remains for about 10 minutes and is then pulled to the surface. If the pipe is "cool," the next charge is placed in the hole; if the pipe is "hot," the hole is not charged.

Practice at another stripping operation is slightly different. Holes 2 inches in diameter and 30 to 40 feet in depth are sprung three times with 1-1/4- by 8-inch cartridges of 40-percent straight nitroglycerin dynamite - first with 3 cartridges, then 10 cartridges, and finally with 20 to 50 cartridges. The main charge is 5 to 8 kegs of FF or FFF granular black blasting powder. A primer of one cartridge of dynamite and an electric detonator are employed to fire the black blasting powder.

Tamping bars are pieces of 1-inch iron pipe about 4 feet long filled with lead to within 2 or 3 inches of the bottom. The bar is attached to a rope and, before the main charge is placed, is lowered to the bottom of the hole with enough force to collect dirt in the hollow end. The bar is hoisted to

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the surface, and if the dirt is "cool" the main charge is placed in the hole. The interval between the firing of one and the placing of succeeding springing charges is not more than 20 minutes, and if holes are wet they are recharged as soon as possible. The opinion of the blasters is that there is not "very much danger in recharging holes with dynamite," an impression that sooner or later is likely to lead to an accident.

At still another operation, where holes 2-1/2 inches in diameter are drilled to a depth of about 25 feet, one charge of 20 cartridges of dynamite - strength not specified - is used to spring the hole. No water is used to cool the holes, but they are allowed to stand at least half an hour or until the blaster considers the holes cool enough, and the main charge of 7 to 10 kegs of blasting powder is placed in the sprung hole. This too is hazardous, and a more definite method should be adopted if accidents are to be avoided.

At a fourth coal-stripping pit holes 2-1/2 inches in diameter are drilled 30 to 50 feet deep in the overburden, and the holes are sprung with 5 cartridges of 1-1/4- by 8-inch, 40-percent-strength gelatin dynamite for the first charge, 18 to 20 cartridges for the second charge, and 50 cartridges for the third and final springing charge. The final charge consists of 5 to 18 kegs of FF black blasting powder.

An interval of at least one-half hour is allowed to elapse between each springing charge and between the last springing charge and the main charge. The blaster uses his judgment as to when the hole is cool enough to insert the charges.

Utah

A typical Utah open pit employs air-driven drills to sink holes about 4 inches in diameter and approximately 23 feet in depth. Most of the holes are drilled on an angle of about 20° below the horizontal and are collared 5 to 6 feet above the toe of a 50-foot bench. When a hole is to be sprung, a 2-inch metal pipe is lowered to the bottom and the springing and main charges as well as primers are loaded through it.

The first springing charge usually is one 1-1/4- by 8-inch cartridge of 60-percent-strength gelatin dynamite and one primer. Holes are sprung from 1 to 5 or even 6 times, the final springing charge being 20 to 30 cartridges. All charges are fired by primers prepared with "cap" and short fuse. A wooden rod about 1 inch in diameter and 25 feet in length is sharpened at one end. This end is inserted into the primer, the fuse is ignited, and the primer is lowered to the bottom of the hole, where it is removed from the wooden rod by rapid rotation of the rod and at the same time striking the cartridge against the lower end of the pipe.

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During drilling the hole is cleaned out from time to time by removing the drill and pouring a bucket of water into the hole. A 1-inch air pipe is inserted into the hole, and the compressed air is turned on, blowing the mud out of the hole. Apparently the walls and bottom of the hole are damp to wet when the springing charges are placed. Water is poured on the final charge before the primer is lighted and inserted in the hole. No other means of cooling the holes are employed.

The interval between springing shots is short, usually 4 or 5 minutes, but the time between firing the last springing charge and the final blast is considerably longer, as 50 to 200 pounds of explosives are required.

Illinois

In a representative quarry in Illinois, holes are drilled 5 inches in diameter and 75 to 80 feet in depth. The holes are sprung with a charge of 50 pounds of 40-percent-strength dynamite or 40 pounds of 60-percent-strength dynamite. An interval of 8 hours elapses between the firing of the springing shot and placing of the main charge in the hole.

Minnesota

One Minnesota open-cut iron-ore mine defers loading a 7-inch-diameter hole to the day following springing, but when 3-inch-diameter holes are sprung the cooling period is 5 to 10 minutes in ore and 15 to 30 minutes in rock. All holes are thoroughly blown out with compressed air before final loading.

Another company tests the temperature of the bottom of the hole by leaving a loading stick in it for about 3 minutes after each springing charge is fired. If the end of the stick is "quite warm, showing considerable heat," water is poured into the hole to cool it; or if water is not available, the blaster waits 10 to 30 minutes after firing each charge, or until the loading stick indicates nearly normal temperature, before loading is begun. After the final springing shot has been fired, if water is not available the hole is allowed to stand 1 to 3 hours to cool to a temperature that "assures" safe loading. Air has been used with fair success to cool "pockets" in holes that are not "ragged." Whenever possible holes are sprung one day and loaded the following day.

Still another company allows the holes to stand approximately 1 hour between the time of springing a hole in ore and placing the final charge. If the hole cannot be left standing that long either water or compressed air is used to cool the spring chamber. Especially deep holes generally are sprung one day and loaded the next.

Elimination of dangers from "hot" holes is obtained in general at one open-pit mine by drilling and springing holes progressively. The final loading and blasting of several deep holes are done at one time, so that, in general, several days elapse between springing and firing of final charges. Where holes must be fired shortly after drilling has been completed, at least 5 hours elapse between firing of the springing charge and loading of the main charge.

The management of another open-pit mine reports that in dry drilling the holes are cooled by pouring water into them or waiting "a sufficient time to allow the hole to cool." Particular care is taken in loading holes drilled in taconite, because heating is greatest in this ore.

Pacific Coast

The general practice on the Pacific coast is to fill the hole with water and allow enough time for the hole to cool after springing before loading with the final charge.

SUMMARY OF CURRENT PRACTICES

Practices vary greatly according to type of material in which the hole is bottomed, the number of times a hole is sprung, and the quantity of explosive used for springing. The waiting period ranges from 4 or 5 minutes to as much as several days. The average interval is difficult to estimate, but it appears that frequently, even where the interval may generally be 1 day, holes are loaded about 30 minutes after the final springing shot is fired.

The interval is determined in several localities by placing a tamping or loading bar in the hole and gaging the temperature by feeling the end with the hand. This method is deceptive, and if paper is burning or smoldering at the bottom of the hole it may prove entirely unreliable.

Compressed air is used more or less sporadically throughout the United States to clean the holes and to cool them. Water is also used to a greater or less extent throughout most of the mining districts where deep holes are drilled, but in many localities the use of water is more or less optional.

CONCLUSIONS AND RECOMMENDATIONS

Causes

Premature explosions while holes are being sprung or sprung holes are being charged usually result from heating of the holes by the springing shots or from burning paper at the bottom of the hole. The danger increases progressively with several springings and with the length of time required for loading. An appreciable amount of time may be required in some instances to raise the temperature of the explosive to the danger point; or, if the explosive starts to burn, an appreciable time may be required before the pressure necessary to cause detonation is reached. Springing shots may often require only about 5 minutes to load and fire, whereas main charges may require one-half hour or more. The larger the springing charge, the greater the amount of heat liberated by it and the greater is the liklihood of heating the surrounding rock and the succeeding charge of explosives.

Natural Cooling

The heat generated by the firing of explosives is somewhat dissipated into the air, but part of it raises the temperature of the surrounding material. In time this heat will also be given up by the rock. The time required for cooling varies with type of rock, depth of hole, and type and amount of explosives used. Some rules suggest a minimum of 2 hours, and this may be long enough in some instances; but where more than 10 pounds of explosives is used in a springing hole, the safest time limit appears to be 24 hours, except where artificial cooling is employed effectively.

Compressed-Air Cooling

The air may undoubtedly be cooled by blowing out the hole with compressed air, but this should be done thoroughly. Even after compressed air has been used, enough time should elapse before loading the hole to preclude the possibility of the extra air having accelerated burning of paper in the bottom of the hole. Where compressed air is used, it appears advisable to wait 2 hours before charging the hole.

Testing Temperature of Air

Thermometers that will record maximum temperatures at least are recommended for determining the temperatures of bore or drill holes. Where thermometers are used holes should not be loaded if the temperature is greater than 80°F., according to one explosive manufacturer's recommendation. Another means of testing temperature is to lower a wooden or metal bar or a short piece of pipe into the hole and after a few minutes to lift it from the hole and feel the end to determine if the bottom of the hole is too hot or if it is cool enough to load. This method is crude and leaves too much to the judgment of the blaster; many accidents result from faulty judgment, so that this method should not be used. Neither the thermometer nor the "feeling" test gives adequate information as to burning paper in the hole; hence these methods should not be considered adequate.

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Cooling with Water

Where water may be used it is by far the safest means of cooling the borehole; it quenches any burning of paper and aids in cooling hot surfaces. If the rock is really hot, that is, above the boiling temperature of water (212° F. at sea level) the water will "sizzle" and give adequate warning. If no "sizzling" is heard and if no steam issues from the hole it is probably safe to load the hole.

Gelatin dynamites are best suited for wet work. Care must be exercised however, in using gelatin dynamite not to allow it to remain in the water too long. After long exposure to water it is possible that nitroglycerin may have separated; this condition may have been responsible for a number of premature explosions. Most of the premature explosions brought to the attention of the Bureau of Mines have occurred in July or some other summer month; the heat may have caused deterioration of the explosives, possibly because of poor storage conditions, and made them more susceptible to the heat in the chambers of sprung drill holes.

SUMMARIZED RECOMMENDATIONS

The safest method of springing holes appears to be to pour water into the holes after each blast to cool the air and rock or other surfaces and to extinguish any burning paper or other materials in the hole. Where water cannot be used, the holes should be cooled with compressed air; then a definite period (at least 2 hours) should elapse before further loading is done. It is better, however, to wait 24 hours, if possible, and the system of springing holes one day and blasting them the next should be followed where feasible.